MALARIA IN THE CHILDREN OF FREETOWN, SIERRA LEONE

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INTRODUCTION

With a view to finding out the amount of malarial infection in the school children of Freetown, and its effect on the child's health, the following investigation was made between July, 1925, and March, 1926. This includes the greater part of the rainy season and four months of the dry season, the rainfall figures for this period, taken from the Sierra Leone Royal Gazette, being :—

July	30·72 inches
August	34·38 ,,
September	22·88 ,,
October	19·74 ,,
November	7·4 ,,
December	0·15 ,,
January	0·0 ,,
February	0·0 ,,
March	0·12 ,,

The work was carried out in conjunction with Dr. M. G. Blacklock, Lady Medical Officer, to all of whose figures I have had the advantage of ready access. Seven schools in different parts of the town were visited and the blood and spleen of every child and, in most cases, the temperature, was examined. The results of the examinations will first be described and an attempt then made to correlate them.

I. EXAMINATION OF SPLEEN

(*a*) *Description of method employed.*

For some time past an accurate method of measuring the spleen of children in a community undergoing a malaria survey has been needed. Christophers (1924a) and Christophers and Khazan Chand (1924) suggested a method of triangulation of the apex of the spleen and a method of correcting the measurement thus found for the size of the child ; their work has been followed in this enquiry, except that new standard measurements suitable for the African child have been made.

The position of the apex, or most projecting part of the spleen, is triangulated by measuring its distance from the mid-line and from the umbilicus. These measurements having been taken there is only one possible position for the apex above the umbilicus (if the apex is below the umbilicus this is noted at the time of examination).

These initial measurements cannot be used in a survey as the same measurement of, say, 10 cms. from the umbilicus would mean a very different sized spleen in a large child from that in a small child. For this reason the initial measurement has to be multiplied by a correction factor based on the size of the child. The following is a broad outline of the method employed in preparing this correction factor, the full details being given subsequently. A child of 60 cms. sitting height was taken as a standard and a standard abdominal chart prepared by examination of over 1,000 children, showing the measurements of that portion of the abdomen within which the spleen lies. In addition to this the ratio of the rate of increase of abdominal measurements to the rate of increase of sitting height was found. Once these two, the standard measurements and the ratio, were known, a formula was prepared by means of which any measurement of a child of known sitting height could be altered

so as to become comparable with one in a child of 60 cms. sitting height. In order to avoid the necessity for measuring the sitting height of every child the formula has been prepared in such a manner that, in practice, the inter-nipple or nipple-umbilical lines might be substituted for it.

Preparation of an abdominal chart. Christophers (1924a) prepared a chart suitable for Indian children ; as some doubt was felt as to whether this was applicable to the African child a new one was prepared in a manner similar to his. The sitting height and a number of other measurements were made of each child, the average of each of these was found and, by means of a correlation table and Galton graph, showing the ratio of variation between these measurements and the sitting height, these averages were reduced to the value they would have in the standard child. The chart is drawn in the following manner :—

Draw a horizontal line 13·1 cms. long, representing a line drawn from the median line of the body to the mid-axillary line at the level of the nipples ; at a point 6·3 cms. from the left end of this, mark a point representing the nipple ; draw a line vertically downwards from each end of this horizontal line, the left representing the median line of the body, the right one the mid-axillary line ; a line drawn from the nipple so as to cut the median line 19·5 cms. from the nipple, will represent the nipple-umbilical line. The costal margin is represented by a curved line cutting the median line 2·5 cms. from the inter-nipple line, the nipple-umbilicus line 7·6 cms. from the nipple, and the mix-axillary line 10·4 cms. from the nipple-axillary line. The chart thus formed, which is reproduced in fig. 1, represents the left upper quadrant of the abdomen and lower quadrant of the chest drawn in a single plane instead of being curved.

The rate of increase of abdominal measurements is taken to be the same as that of the nipple-umbilicus line. When the different values of this and the sitting height are compared by means of a correlation table and Galton graph, it is found to have a ratio of variation of 0·8 ; that is, for every increase of 1 per cent. in the sitting height there is an increase of 0·8 per cent. in the nipple-umbilicus line and in other abdominal measurements.

As our standard is a child of a certain sitting height it would be correct, in all cases where it is desired to use this correction

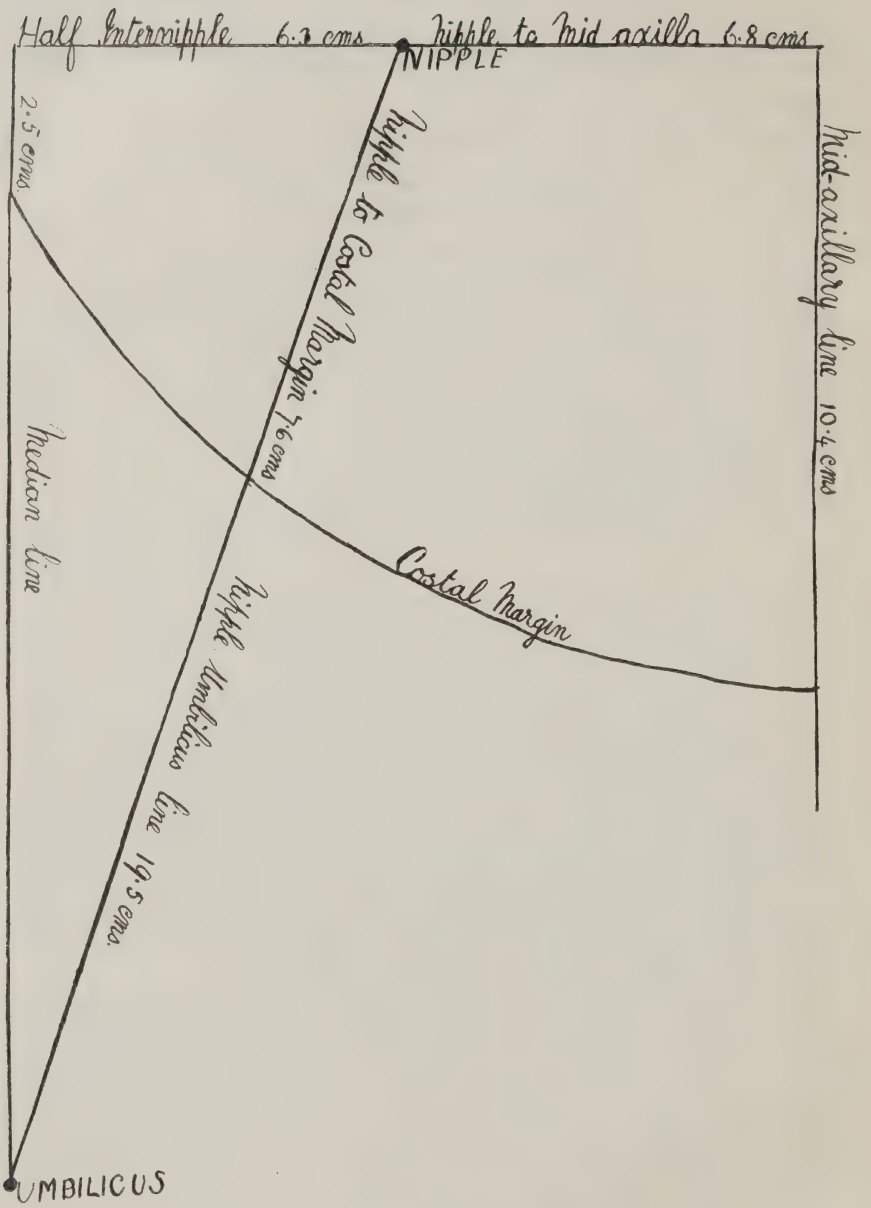

FIG. 1. Standard abdominal chart, drawn in the manner described on p. 241.

factor, to take the sitting height of the child as an indicator measurement ; this, however, is an inconvenient measurement to take, whereas the nipple-umbilicus line and inter-nipple line are always easily measured at the time of triangulation of the spleen. Any one of these three may therefore be taken and the splenic measurement corrected by reference to Table I, in the vertical columns of which are the corrected values of the observed measurement for different values of the sitting height, inter-nipple line and nipple-umbilicus line.

The use of these two thoracic and abdominal measurements as indicators is justified by convenience when a number of children are being examined and the average size of spleen in a district is wanted. In the case of individual children, however, it is not justified and the use of anything but the sitting height as an indicator may lead to errors of 2 cms. in the corrected value of a measurement. When a number of children are being examined, however, these inaccuracies, which are only few and rarely as great as the above, are negligible, as may be seen by reference to Table II, in which the children are divided into small groups and the average distance of the spleen from the umbilicus is given corrected by each of the three indicator measurements. Children in whom the spleen was recorded as ' at the costal margin ' or ' palpable ' and children in whom not all three indicators were measured are not included in this table, so that the numbers are smaller than in succeeding ones.

(*b*) *Application of method in practice.*

Method of measurement of the spleen. The spleen is palpated preferably with the child in the standing position—when necessary the child may be told to bend down and breathe deeply—and if palpable the position of the apex is marked on the abdominal wall with a grease pencil. The distance of this point from the mid-line and from the umbilicus, and the length of one of the indicator measurements are taken with a tape marked in centimetres ; if the spleen is below the umbilicus or is ' at the costal margin ' or only ' palpable but not reaching the costal margin ' the fact is noted.

These data are entered in a book and at a later time the splenic measurements are corrected. If it is desired to obtain only the average distance of the apex from the umbilicus this is sufficient ;

TABLE I.

Correction Table. The vertical columns show the corrected values of the measurements in the top horizontal column for different values of the sitting height (S.H.), inter-nipple line (I.N.), and nipple-umbilical line (N.U.).

S.H.	I.N.	N.U.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
40	...	14	1	3	4	5	7	8	10	11	12	14	15	16	18	19	20	22	23	25	26	27
41	9	...	1	3	4	5	7	8	9	11	12	13	15	16	17	19	20	21	23	24	25	27
42	...	...	1	3	4	5	7	8	9	11	12	13	14	16	17	18	20	21	22	24	25	26
43	...	15	1	3	4	5	6	8	9	10	12	13	14	16	17	18	19	21	22	23	25	26
44	...	...	1	3	4	5	6	8	9	10	11	13	14	15	17	18	19	20	22	23	24	25
45	...	...	1	2	4	5	6	7	9	10	11	12	14	15	16	17	19	20	21	22	24	25
46	10	...	1	2	4	5	6	7	9	10	11	12	14	15	16	17	18	20	21	22	23	25
47	...	16	1	2	4	5	6	7	8	10	11	12	13	15	16	17	18	19	21	22	23	24
48	...	...	1	2	4	5	6	7	8	10	11	12	13	14	15	17	18	19	20	21	23	24
49	...	...	1	2	4	5	6	7	8	9	11	12	13	14	15	16	18	19	20	21	22	23
50	...	17	1	2	3	5	6	7	8	9	10	12	13	14	15	16	17	18	20	21	22	23
51	...	...	1	2	3	5	6	7	8	9	10	11	12	14	15	16	17	18	19	20	22	23
52	11	...	1	2	3	4	6	7	8	9	10	11	12	13	15	16	17	18	19	20	21	22
53	...	...	1	2	3	4	6	7	8	9	10	11	12	13	14	15	17	18	19	20	21	22
54	...	18	1	2	3	4	5	7	8	9	10	11	12	13	14	15	16	17	18	20	21	22
55	...	...	1	2	3	4	5	6	8	9	10	11	12	13	14	15	16	17	18	19	20	21
56	...	...	1	2	3	4	5	6	7	8	10	11	12	13	14	15	16	17	18	19	20	21
57	12	...	1	2	3	4	5	6	7	8	9	10	11	12	14	15	16	17	18	19	20	21
58	...	19	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	20	21
59	...	...	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
60	...	...	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
61	...	...	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
62	13	20	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	17	18	19
63	...	...	1	2	3	4	5	6	7	8	9	10	11	12	12	13	14	15	16	17	18	19
64	...	...	1	2	3	4	5	6	7	8	9	10	10	11	12	13	14	15	16	17	18	19
65	...	...	1	2	3	4	5	6	7	7	8	9	10	11	12	13	14	15	16	17	18	19
66	...	21	1	2	3	4	5	6	6	7	8	9	10	11	12	13	14	15	16	17	18	19
67	14	...	1	2	3	4	5	5	6	7	8	9	10	11	12	13	14	15	16	17	17	18
68	...	...	1	2	3	4	5	5	6	7	8	9	10	11	12	13	14	14	15	16	17	18
69	...	...	1	2	3	4	4	5	6	7	8	9	10	11	12	12	13	14	15	16	17	18
70	...	22	1	2	3	4	4	5	6	7	8	9	10	11	11	12	13	14	15	16	17	18
71	...	...	1	2	3	3	4	5	6	7	8	9	10	10	11	12	13	14	15	16	17	17
72	15	...	1	2	3	3	4	5	6	7	8	9	9	10	11	12	13	14	15	16	16	17
73	...	23	1	2	3	3	4	5	6	7	8	9	9	10	11	12	13	14	14	15	16	17
74	...	...	1	2	3	3	4	5	6	7	8	8	9	10	11	12	13	13	14	15	16	17
75	...	...	1	2	3	3	4	5	6	7	7	8	9	10	11	12	13	13	14	15	16	17
76	...	...	1	2	2	3	4	5	6	7	7	8	9	10	11	12	12	13	14	15	16	16
77	...	24	1	2	2	3	4	5	6	7	7	8	9	10	11	11	12	13	14	15	15	16
78	16	...	1	2	2	3	4	5	6	6	7	8	9	10	10	11	12	13	14	15	15	16
79	...	...	1	2	2	3	4	5	6	6	7	8	9	10	10	11	12	13	14	14	15	16
80	...	25	1	2	2	3	4	5	6	6	7	8	9	9	10	11	12	13	13	14	15	16

In the few cases where greater accuracy is required than can be got from the table, use may be made of the following formula which is a slight modification of that given by Christophers.

$$A = a \frac{1}{1 + \frac{r}{R}\left(\frac{h}{H} - 1\right)}$$

Where A is the required abdominal measurement.
Where a is the observed abdominal measurement.
Where r is the ratio of variation of abdominal measurements (0·8).
Where R is the ratio of variation of indicator measurement taken.
Where b is the observed indicator measurement.
Where H is the standard indicator measurement.

The ratio of variation and 'standard lengths' are :—	Ratio of variation	'Standard length'
Sitting height	1·0	60 cms.
Inter-nipple line	0·9	12·6 cms.
Nipple-umbilicus line...	0·8	9·5 cms.

Where the nipple umbilicus line is used as an indicator $\frac{r}{R} = 1$ and when the sitting height is used $\frac{r}{R} = .8$.

but if it is desired to study the path of descent of the spleen the corrected values can be entered on the chart. Christophers (1924a) gives the following directions for doing this 'since every double measurement indicates a definite point on the abdomen the position of the apices of the spleens in any series can be marked on the standard abdominal chart. For this purpose the chart may be ruled with two sets of lines, one being circles giving distances of 1, 2, 3, etc., cms. from the umbilicus, the other being straight lines drawn parallel to the median line of the body at distances of 1, 2, 3, etc., cms.

Table II.

Showing the average size of spleen in each school. Spleens projecting below the costal margin alone included.

School	Number measured	Average distance from umbilicus corrected by		
		Sitting height	Internipple line	Nipple-umbilicus line
Model School	22	7·8 cms.	7·9 cms.	7·8 cms.
Cathedral Infants	33	7·3 cms.	7·3 cms.	7·3 cms.
Holy Trinity	39	9·0 cms.	9·1 cms.	8·9 cms.
St. Edward's	22	9·9 cms.	9·8 cms.	9·7 cms.
Bethel Wesleyan	59	9·3 cms.	9·4 cms.	9·5 cms.
St. Joseph's	60	8·1 cms.	8·3 cms.	8·3 cms.
St. Anthony's	130	8·8 cms.	8·8 cms.	8·8 cms.
Buxton	80	8·7 cms	8·6 cms.	8·8 cms.

So that the spaces and not the lines should correspond to these measurements, the standard chart has been ruled with lines at distances of $1\frac{1}{2}$, $2\frac{1}{2}$, $3\frac{1}{2}$, etc., cms.; the spaces therefore correspond to measurements of 1, 2, 3, etc., cms. The lines form a series of diamond-shaped spaces each equivalent to a spleen measurement on the double notation. Into each space, therefore, can be entered the number of spleens showing this particular measurement.'

A chart constructed in this manner giving the position of the apices of the spleens of the hyper-endemic area, referred to later, is shown in fig. 2.

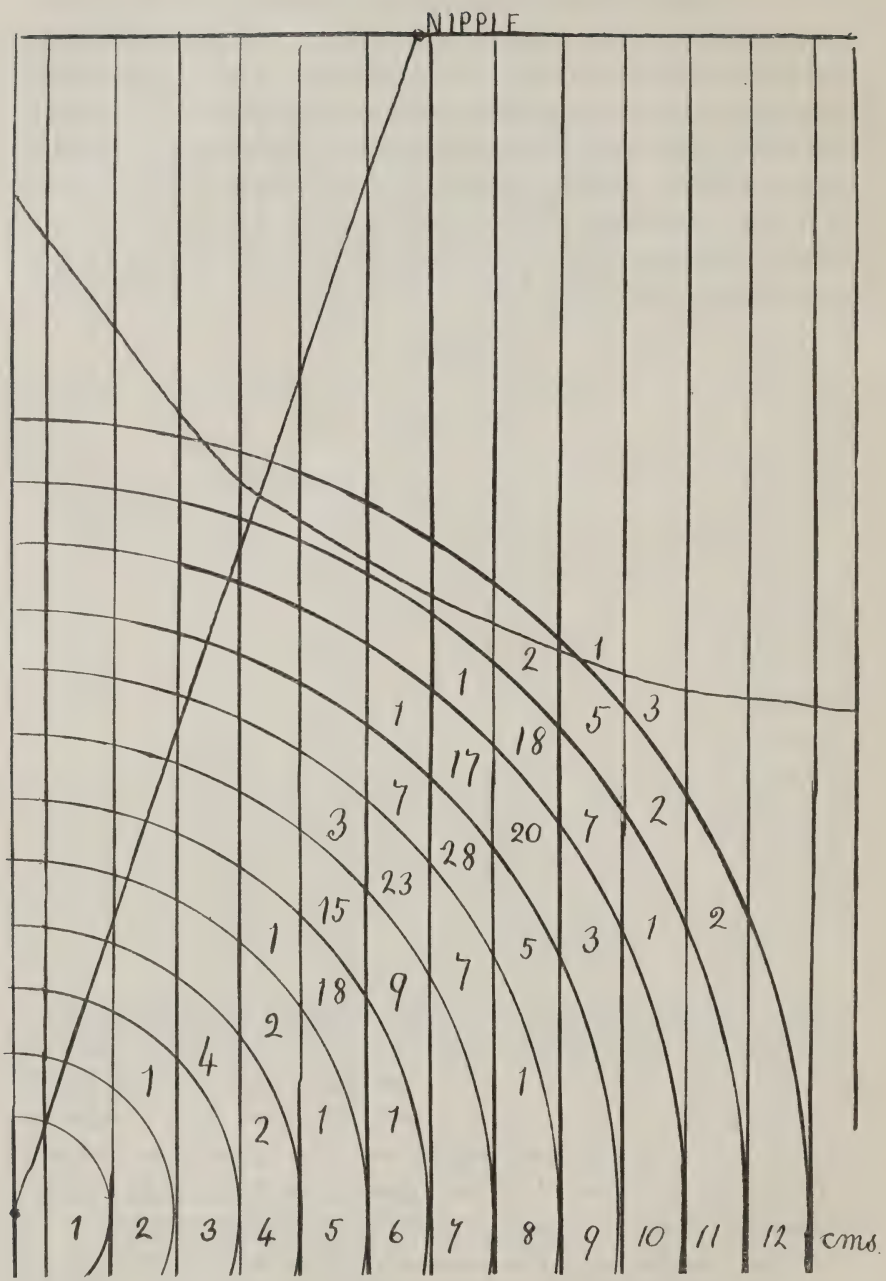

FIG. 2. Standard abdominal chart, ruled as suggested by Christophers, with the spleens of the hyper-endemic area entered on it. Owing to the limitations of space, spleens projecting below the umbilicus are not shown. The figures represent the number of apices in each space.

Christophers (1924a) states that for the expression of a value for the size of the enlarged spleen in a community the position of the mean on the progression line of the apex is required. This has a serious disadvantage, in that no value is given by this method to spleens which cannot be measured because they are only ' at the costal margin ' or ' palpable but not reaching the costal margin.' He was, however, working in a hyper-endemic area where such spleens formed no large part of the whole, but in some districts in Freetown, districts where the severity of malarial infection is slight, such spleens may form half of the palpable spleens and their omission when calculating the mean would lead to serious error. This difficulty could be surmounted by assigning to these spleens their proper value. The malarial spleen usually passes under the costal margin in the standard child at a point about 13 cms. from the umbilicus ; the normal position of the apex of the un-enlarged spleen is probably in the mid-axillary line about 17 cms. from the umbilicus in the standard child ; and the ' just palpable ' spleen probably lies, on the average, about half-way between the two, i.e., 15 cms. from the umbilicus. In calculating the mean distance of the spleen from the umbilicus the ' costal margin ' and ' just palpable ' spleens might be given respectively the values of 13 and 15 cms. ; the mean would then give a much more complete picture of the degree of splenic enlargement.

(*c*) *Results of Examination.*

One thousand and fifty-nine children were examined in the manner described, and of those 604 (57 per cent.) had palpable spleens. The number of children aged ten or under examined was 852 ; of these 475 had palpable spleens so that the spleen index of Ross (1910) is 56.

It became obvious later in the enquiry that part of the town, the extreme West, came under Christophers' (1924b) definition of a hyper-endemic area—one in which the spleen rate (children) is permanently over 50 per cent.—and part, the Central and Eastern portion, that of an endemic area—areas, i.e., showing moderate to high, but often variable, spleen rates not permanently over 50 per cent. This difference was noted despite the fact that the endemic

area was examined during what is normally the most malarious season of the year, the wet season and early part of the dry season, while the hyper-endemic area was examined during the latter part of the dry season, the relatively healthy period before the first showers of the year.

The Central and Eastern part of the town is, for the most part, on a slight but definite slope, and has two streams running through it —Nicol's Brook and the stream opening at Magazine Wharf. The extreme Western portion of the town is low-lying and through it run Sanders Brook and Alligator Brook.

Blacklock and Evans (1926) in discussing the distribution of *A. costalis*, the commonest Freetown anopheline, state that its larvae were found in all four of these streams, but whereas in Nicol's Brook they were mainly found below and on the outskirts of the town, and in the Magazine Wharf stream only below the town, in Sanders Brook it was notable that they occurred where the laterite drains from the streets join the stream, actually in the town. In the fact that the commonest vector is here breeding in the near vicinity of the house, even at the end of the dry season, we appear to have the explanation of the heavier infection in the Western part. As these two areas present marked differences they will here be described separately.

(1) *Endemic Area.*

Of the total 1,059 examined, by far the majority, 722, of the children seen came from this district and of these 360 (50 per cent.) had enlarged spleens ; the percentage of children of ten and under with enlarged spleens was 49, and the average distance of the spleen from the umbilicus, including palpable and costal margin spleens, was 10·5 cms. These spleens were not, however, distributed evenly along the line of progression, but were grouped about two distinct sizes, one a small size, consisting of spleens not projecting below the costal margin—123 spleens fell within the class—and a larger size, consisting of spleens 7-10 cms. from the umbilicus, into which group fell 150 spleens ; the intervening medium size and the larger sizes only accounting for forty-eight and thirty-nine respectively. This is in agreement with the work of Christophers (1924b), who found that the spleens he examined in the Singhbhum

district fell into three classes, small, medium, and large (though the spleens in each group were larger than those in the corresponding group here) ; the medium group was characteristic of the period of ' acute infestation ' that is, the first two or three years of life, after which, in the period of ' immune infestation ' (' premunition ' (Sergent, Parrot, and Donatien, 1925)) the small and large groups grew at its expense. In the Freetown investigation practically all the children examined were well within the period of immune infestation, so that it is not unnatural that there should here be such a marked separation into two main groups.

Relation between the spleen and parasite findings. That there is a definite relation between the presence of an enlarged spleen and the probability of finding parasites in the blood is, of course, well known, and in this endemic area series, of the 362 children without enlarged spleens only 98 (27 per cent.) had positive blood findings, while of the 360 with enlarged spleens 200 (56 per cent.) had parasites in their blood. The relation, however, between the size of the spleen and the parasite findings is not so clear. When a table is prepared showing the size of spleen in association with which positive blood findings most commonly occur the latter are found to be grouped round two different sizes of spleens ; but further investiga-

TABLE III.

Showing the relation between size of spleen and presence of parasites in blood.

Size of spleen	Number	Percentage of all spleens	Number of positive bloods	Percentage of positive bloods in persons with palpable spleens
Just palpable	71	20	32	16
At costal margin	52	14	33	16·5
14 cms. from umbilicus ...	1	0	0	0
13 cms. ,, ...	6	2	3	1·5
12 cms. ,, ...	16	4	10	5
11 cms. ,, ...	25	7	11	5·5
10 cms. ,, ...	31	9	20	10
9 cms. ,, ...	39	11	16	8
8 cms. ,, ...	44	12	21	10·5
7 cms. ,, ...	36	10	27	13·5
6 cms. ,, ...	20	6	15	7·5
5 cms. ,, ...	12	5	6	6
4 cms ,, ...	3		3	
3 cms . ,, ...	3		2	
3 cms. below umbilicus ...	1		1	

tion shows that these are the commonest sizes of spleen. In Table III the number of spleens of each size, the percentage they form of all the palpable spleens, together with the number of positive bloods and the percentage they form of positive bloods in persons with palpable spleens, are shown, and it will be seen that the two percentages agree closely ; it is particularly noticeable that the largest spleens are not associated with diminished parasite findings.

Age incidence of splenic enlargement. The percentage of children with palpable spleens, shown in Table IV, remains practically constant throughout the age period examined ; there does, it is true, appear to be a slight increase in the 11-12 group, but the increase and the number of children examined are not sufficiently large to justify the assumption that this is real and not merely due to the error of random sampling. The size of the spleen, shown in the same table, also appears to remain fairly constant.

TABLE IV.

Showing the age incidence of blood and spleen findings in the endemic area.

Age	Number examined	Percentage with Positive blood	Percentage with palpable spleen	Average distance of enlarged spleen from umbilicus
3– 4	23	43	48	9·5 cms.
5– 6	145	46	52	10·4 cms.
7– 8	211	39	48	10·2 cms.
9–10	207	41	49	10·5 cms.
11–12	117	40	55	10·4 cms.

Splenic measurements corrected by sitting height; spleens noted as 'palpable, but not reaching costal margin,' and 'at costal margin,' are included.

N.B.—The few children aged thirteen or over, and those of doubtful age, are omitted from this and all subsequent tables showing age incidences.

(2) *Hyper-endemic Area.*

Of the 337 cases that occurred in the hyper-endemic area 244 (72 per cent.) had palpable spleens. Two hundred and sixty-five were aged ten or under and of these 183 (71 per cent.) had palpable spleens, so that the spleen index of Ross (1910) is 71, the average distance of the spleen from the umbilicus was 8·1 cms., considerably less than in the endemic area. The positions of the apices did not, however, show that division into two distinct groups which was

present in the endemic area, but were more or less evenly distributed about a mode at 8-9-10 cms. from the umbilicus.

Age incidence of splenic enlargement. In this area there is not the same relation between splenic enlargement on the one hand and age or parasite findings on the other, as in the endemic area. In Table V, in which blood and spleen findings are grouped in two-yearly age groups, the numbers being too small to allow of grouping in single year periods, it will be seen that the spleen rate falls from 86 per cent. during the 5-6 age group, to 60 per cent. at the age of ten, after which it returns to 81 per cent. in the 11-12 age group. Thus from being considerably higher than the parasite rate it drops to 20 per cent. below it and recovers to a point 20 per cent. above it again.

TABLE V.

Showing the age incidence of blood and spleen findings in the hyper-endemic area, and the average distance of the spleen from the umbilicus at different ages.

Age	Number examined	Percentage with positive blood	Percentage with palpable spleen	Average distance from umbilicus
3- 4	5	80	80	11·75 cms.
5- 6	80	75	86	8·5 cms.
7- 8	94	72	65	9·2 cms.
9-10	86	80	60	8·7 cms.
11-12	70	60	81	9·2 cms.

It is difficult to find an explanation for this drop after the age of six. It cannot be explained on the grounds of a difference in technique, as this was the same throughout and children of different age groups were examined side by side every day. The numbers examined in each age group seem substantial, but a repetition of the observation must be made on still larger numbers of children before the decrease and subsequent increase can be accepted as facts and have theories built on them.

Relation between the size of spleen and age. The size of the spleen, the variations in which are also shown in Table V, appears here to remain more or less constant at all the ages examined, excepting the 3-4 group, in which the number of children examined was too small to enable one to draw any conclusions from them.

The relation between size of spleen and parasite findings. In this area the relation between the presence of an enlarged spleen and the probability of finding parasites in the blood is not so great. Of the 93 without palpable spleens, 61 (66 per cent.) had positive bloods, while of the 244 with enlarged spleens, 183 (75 per cent.) were positive. The size of spleen showed the same relation to parasite findings as in the endemic area and it was again noted that the largest spleens were not associated with any diminution in the parasite findings, in fact, of the thirty-seven spleens projecting to within 6 cms. or less of the umbilicus, thirty-two (86 per cent.) were associated with an infected blood. The details of this are shown in Table VI.

TABLE VI.

Relation between size of spleen and parasite findings.

Size of spleen	Number	Percentage of all spleens	Number of positive bloods	Percentage of positive bloods in persons with spleens
Just palpable	11	4·5	8	4
Costal margin	15	6	9	5
13 cms. from umbilicus ...	4	2	3	2
12 cms. ,, ...	11	4·5	9	5
11 cms. ,, ...	27	11	18	10
10 cms. ,, ...	41	17	31	17
9 cms. ,, ...	40	16	31	17
8 cms. ,, ...	34	14	25	14
7 cms. ,, ...	24	10	17	9
6 cms. ,, ...	20	8	17	9
5 cms. ,, ...	3		2	
4 cms. ,, ...	6		6	
3 cms. ,, ...	1		1	
3 cms. below umbilicus ...	2	7	2	8
4 cms. ,, ...	2		2	
5 cms. ,, ...	2		1	
8 cms. ,, ...	1		1	

II. EXAMINATION OF PERIPHERAL BLOOD

A single thin film was taken from the ear of each child and examined after staining with Giemsa. No film was pronounced negative until it had been examined for at least ten minutes ; one thousand and fifty-nine films were thus examined and 542 (51 per cent.) showed malaria parasites.

(*a*) *Endemic area.*

Of the 722 children examined here, 298 (41 per cent.) had infected bloods. Benign Tertian, Quartan and Malignant Tertian parasites were all seen, the latter by far preponderating. Below are shown the number of each species, the three double infections being counted under both parasites :—

Malignant tertian	251	83 per cent.
Quartan	41	14 „
Benign tertian	5	2 „
Infections diagnosed on pigmented leucocytes only ...	4	1 „

Age incidence of malaria findings. Table VII shows the percentage of children infected at each age group from 3 to 12. This remains steady at approximately 40 per cent. during the whole of the age period examined.

Table VII.

Showing the age incidence of parasite findings in the endemic area.

Age	Number examined	Percentage with positive blood
3– 4	23	43
5– 6	145	46
7– 8	211	39
9–10	207	41
11–12	117	40

(*b*) *Hyper-endemic area.*

Of the 337 children whose blood was examined, 244 (72 per cent.) had malaria parasites in their blood, Quartan and Benign tertian

infections being slightly more common than in the endemic area, the actual numbers being :

Malignant tertian	191	78 per cent.
Quartan	46	19 „
Benign tertian	6	2 „
Infections diagnosed on pigmented leucocytes only ...	1	1 „

The age incidence of these infections, which is seen in Table VIII, remained stationary, as in the endemic area, till the age of ten, the rate ranging round 75 per cent., but then showing a sharp fall to 60 per cent.

TABLE VIII.

Showing the age incidence of parasite findings in the hyper-endemic area.

Age	Number examined	Percentage with positive blood
3- 4	5	80
5- 6	80	75
7- 8	94	72
9-10	86	80
11-12	70	60

III. THE INTENSIVE EXAMINATION OF CHILDREN

Although the parasite rate and spleen rate in the endemic area were both below 50, it was suspected that a much larger percentage of the children than this was infected with malaria. A school was therefore chosen, in which the children were under good discipline, and fifty-six boys were examined daily (or until found positive), not more than seven examinations, however, being made of any child. Of these fifty-six, five proved to have taken quinine for 'fever' within three days of the commencement of examination, one refused examination after the third time and one remained absent after the second examination ; these seven were all disqualified and do not appear in the following figures. Of the remaining forty-nine the results for a single examination were :—

Number with positive blood film	23	47 per cent.
Number with enlarged spleen	24	49 „

The subsequent examinations revealed malaria in nineteen more of the children, making a total of forty-two (85·7 per cent.) with positive blood films. One of these nineteen had also been taking quinine within a week of examination and was diagnosed on pigmented leucocytes alone. Of the seven who remained negative after seven consecutive examinations, two had enlarged spleens, two had temperatures of 99·4° F., two had temperatures of 99° F., one only being entirely normal, with a temperature of 98·6° F., no palpable spleen and a consistently negative blood film. Of these 49 children, therefore, 48 (98 per cent.) showed definite evidence of illness, and in 42 (86 per cent.) this illness was definitely malaria.

The age grouping of these children was as follows :—

Age	Number examined	Positive first examination	Positive at any examination
5–10	33	16 = 48 %	29 = 88 %
11–16	17	6 = 35 %	13 = 76 %

The figures are too small to draw any definite conclusions as to the age grouping of these infections, but suggest that the older group of children is more lightly infected as is shown by either single or repeated examinations.

A similar examination was made of the children attending School in Murray Town, a small village outside Freetown, in which a single examination gave results comparable to the endemic area already described ; thirty-seven children were here examined, the results for a single examination being :—

Number examined	37		
Number with positive blood film	18	=	49 per cent.
Number with palpable spleen	17	=	46 „

The six subsequent examinations showed parasites in another thirteen, so that thirty-one (84 per cent.) were finally found infected. Of the remaining six, one had a temperature of 100° F. and an enlarged spleen, two had temperatures of 100° F., one had a temperature of 99·8 °F., and two had temperatures of 99·6° F., so

that the entire thirty-seven were suffering from some disease, in all probability malaria.

The combined figures for the two schools examined in this intensive way are :—

Number examined	86		
Number with palpable spleen	41	=	48 per cent.
Number with positive film on first examination ...	41	=	48 „
Number with positive film at any examination ...	73	=	85 „

while, of the remaining thirteen, twelve had either a high temperature or a palpable spleen. It would appear from the above that the true difference between a hyper-endemic and an endemic area is not that a much higher percentage of children are infected in the former, but that the severity of infection is greater, probably due to a higher inoculation rate. In both districts the children are continually suffering from malaria, but in the endemic area the child has the disease under control for a large part of the time, a decrease in the parasite index being produced either by a decrease in the inoculation rate, or by an increase in the immunity of the child, and not by a decrease in the number of children infected.

The absence of an enlarged spleen probably signifies relatively light infection, one, that is, in which the child's peripheral blood does not constantly contain malaria parasites, but gives little clue as to whether or not they will be seen on repeated examination ; thus, of the forty-one with enlarged spleens in these two schools, twenty-six (63 per cent.) showed parasites in a single examination and on subsequent examination thirty-eight (93 per cent.) were positive. Amongst the forty-five without enlarged spleens only fourteen (31 per cent.) were positive on the first day, but the number was increased on subsequent examination to thirty-five (78 per cent.).

Concentration of malaria round Anopheline breeding places. The restriction of malaria to the immediate vicinity of anopheline breeding places has been pointed out by Ross (1910) and others, while Blacklock (1921) and Blacklock and Evans (1926) have shown the dependence of the anophelines in Freetown on the streams. In order to confirm these and the statements that have previously been made about the cause of difference in the severity of infection in the two districts, two areas were chosen and the condition of the blood of all children living in them noted.

The first area (area *A*) was a square in the centre of the town, bounded by Oxford Street, Garrison Street, and Pademba Road, Percival Street and Wilberforce Street, on a gentle slope, well drained and no part of it less than a quarter-of-a-mile from the nearest breeding place in the spot map shown in Blacklock and Evans' (1926) paper. The second area (area *B*) consisted of a number of short streets in the region of Sanders Brook, none of them extending to more than a quarter-of-a-mile away from the nearest breeding place in the map. These two areas are not far separated, the Eastern border of one approaching within two hundred yards of the Western border of the other. Sixty-six children from the first area were examined and seventeen (26 per cent.) had malaria parasites in their blood ; whilst of 78 children who were seen from the district along the bank of the stream, 49 (63 per cent.) were positive. The map of Blacklock and Evans (1926) showing anopheline breeding places, is reproduced (by permission) in fig. 3, with areas *A* and *B* marked on it.

IV. THE EXAMINATION OF TEMPERATURES

The mouth temperature of most of the children (unfortunately not all, as this was started a week or so late) was taken with an N.P.L.* stamped thermometer which, though not locally tested against a standard thermometer, gave normal readings in Europeans.

Of the one thousand and seven children whose temperatures were taken, in the whole town only 61 (6 per cent.) were below 99° F., 528 (52 per cent.) were between 99° and 99·9° F., while the remaining 418 (42 per cent.) were 100° F. or over. This preponderance of raised temperatures has been noted before by Butler (1913), in Freetown, and by Magill (1923), in Accra and Seccondi ; both of these observers noted the apparent lack of relation of the high temperature to the finding of malaria parasites in the blood, and the latter remarks that 98·4° F. can hardly be regarded as the normal for the African School child.

Tables IX and X below show the incidence of the various temperatures.

*National Physics Laboratory.

TABLE IX.

	Endemic Area		Hyper-endemic Area	
	Number	Percentage	Number	Percentage
Number of temperatures taken	672	...	335	...
Below 99°	60	9	1	0·3
99–99·9°	384	57	144	43
100° and over	228	34	190	57

TABLE X

Showing the age of incidence temperatures of 100° F. and over.

A. ENDEMIC AREA.

Age	3	4	5	6	7	8	9	10	11	12
No. of temperatures taken	2	20	50	75	99	98	104	101	81	30
Percentage 100° F. or over	50	50	30	43	34	45	33	32	26	17

B. HYPER-ENDEMIC AREA.

Age	3	4	5	6	7	8	9	10	11	12
No. of temperatures taken	3	2	16	64	51	41	48	39	40	29
Percentage 100° F. or over	...	...	62	58	61	63	67	59	55	21

It will be seen that in each area the percentage with high temperatures varies about a mean between the ages of 5 and 10 years, 60 per cent. in the case of the hyper-endemic area, 40 per cent. in the endemic area, and then shows a marked decrease, coinciding with the decrease in the parasite index.

There was no observed relationship between the occurrence of a temperature of 100° F. or over, and the finding of malaria parasites or a palpable spleen, as is shown below :—

TABLE XI

Showing the relation between blood, spleen and temperature findings.

	Percentage with temperature of 100° or over	
	Endemic area	Hyper-endemic area
Children with positive blood	34	55
Children with negative blood	34	62
Children with palpable spleen	35	57
Children without palpable spleen	33	56

Despite the apparent lack of relationship between parasite and spleen findings and the temperature, shown here and in Butler's and Magill's work, I consider that the normal temperature of the African school child is the same as that of the European and that the high temperature is due to malaria, for the following reasons :—

(1) It is the experience of medical practitioners practising medicine locally that the administration of quinine to children rapidly brings the temperature to 98·4° F. or thereabouts, and that this is the normal temperature in the adult.

(2) The incidence of the high temperatures coincides with that of parasite findings ; thus in the less heavily infected area, with a parasite rate of 41 per cent., 34 per cent. had temperatures of 100° F. or over ; in the hyper-endemic area, parasite rate 72 per cent., 57 per cent. had these temperatures. Dr. Magill (1923), working in Accra, examined 288 children with a parasite rate of 19 per cent., and only 40 (14 per cent.) had temperatures of this height. Butler, unfortunately, does not give the number of children with temperatures of 100° F.

(3) The changes in the incidence of high temperatures at different ages are very similar to those in the parasite rate.

We may therefore take it that the high temperatures in school children living in malarious countries is due to malaria, that the percentage of children with these temperatures serves as an indication of the parasite and spleen rates, but it cannot be assumed that

because any individual child has a temperature of 100° F. or over that it therefore has parasites in the peripheral blood at the time.

Malaria amongst Mulattos. The frequency of enlarged spleens in mulatto children was noticed by Magill (1923), in Accra, where amongst the sixty mulattos examined, 59 per cent. had enlarged spleens, against 16 per cent. amongst native children.

In this examination only thirty-three mulattos were seen, nineteen boys and fourteen girls. Twelve came from the hyper-endemic area, all of these had palpable spleens, the average distance from the umbilicus being 7·8 cms. Nine (75 per cent.) had temperatures of 100° F. or over, and five (42 per cent.) had positive bloods. Twenty-one lived in the endemic area, of whom seventeen (81 per cent.) had palpable spleens, on the average 9·1 cms. distant from the umbilicus, six (29 per cent.) had positive bloods, and of the twenty whose temperature was taken, in nine (45 per cent.) it was 100° F. or over.

It would appear from the above that in both areas the mulatto children have higher temperature rates and spleen rates, larger spleens and lower parasite rates than the native children. The number of them examined, however, is too small to permit of any reliable conclusions being drawn.

SUMMARY

1. One thousand and fifty-nine children, aged 3 to 12, in the schools of Freetown, Sierra Leone, were examined for the condition of their blood, spleen, and temperature, between July, 1925, and March, 1926.

2. Abdominal measurements were made of all children and a method of correction of splenic measurements for the size of the child, similar to that of Christophers (1924a) was devised.

3. It was found possible to divide the town into two areas, a hyper-endemic area in close proximity to the breeding places of *A. costalis*, and an endemic area remote from them.

4. The spleen rates in the endemic and hyper-endemic area respectively were 50 and 72, and the parasite rates 41 and 72.

5. In the endemic area there was no sign of diminution of the spleen or parasite rate during the age examined; in the hyper-

endemic area, however, the parasite rate diminished at the age of twelve.

6. It was shown by the intensive examination of 86 children living under endemic conditions that although only 48 per cent. had parasites in their peripheral blood at a single examination, yet at least 85 per cent. were suffering from malaria.

7. The cause of the varying severity of malaria in different districts of the town was demonstrated by selecting two areas, one containing numerous anopheline breeding places, one only a few or none, and comparing the condition of the children in each.

8. Thirty-three mulattos were seen and it is suggested that possibly they re-act to malarial infection in a different manner from pure negroes.

9. The temperature of over 1,000 children was taken and it was found that a temperature conforming to a normal of 98·4° F. was a comparative rarity. Evidence is given which goes to prove that this is not due to the African's normal temperature being higher than that of the European, as suggested by some, but is a pathological rise due to malaria. It is possible that in the elevation of the temperature we have a more accurate indication of malarial infestation in endemic areas than in either the parasite or the spleen rate.

REFERENCES

Blacklock, B. (1921). Breeding Places of Anopheline Mosquitos in Freetown, Sierra Leone. *Ann. Trop. Med. & Parasitol.*, Vol. XV, No. 4, p. 463.

Blacklock, D. B., and Evans, A. M. (1926). Breeding Places of Anopheline Mosquitos in and around Freetown, Sierra Leone. *Ann. Trop. Med. & Parasitol.*, Vol. XX, No. 1, p. 59.

Butler, G. G. (1913). Annual Report on the Medical Department of Sierra Leone for the year ended 31st December, 1913, p. 41.

Christophers, S. R. (1924a). The Shape and Position of the Palpable Portion of the Enlarged Spleen in Children. *Ind. Journ. Med. Res.*, Vol. XI, No. 4, p. 1081.

——— (1924b). The Mechanism of Immunity against Malaria in Communities living under Hyperendemic Conditions. *Ind. Journ. Med. Res.*, Vol. XII, No. 2, p. 273.

Christophers, S. R., and Khazan Chand (1924). Measurement in centimetres of the enlarged spleen in children and its correction for size of child by a factor based on an anthropometric measurement. *Ind. Journ. Med. Res.*, Vol. XI, No. 4, p. 1065.

Magill, E. M. (1923). Report on the Medical Inspection of School Children in Accra during 1923, p. 31.

Ross, R. (1910). The Prevention of Malaria, London, 1910, p. 187.

Sergent, E., Parrot, L., and Donatien, A. (1925). On the Necessity of having a Term to express the Resistance of Carriers of Germs to Superimposed Infections. *Trans. Roy. Soc. Trop. Med.*, Vol. XVIII, No. 7. p. 383.

MAP OF FREETOWN

Showing anopheline breeding places, reproduced by permission, from Blacklock and Evans (1926). The two areas, A and B, marked on it are those referred to on page 257. The parasite index of B, where anopheline breeding places are numerous, was 63 per cent. and that of A, which is devoid of them, was 26 per cent. The hyper-endemic area consists of area B and the district to the east of it; the endemic area is to the west of area B.